US008561829B1

(12) United States Patent
DeLay

(10) **Patent No.: US 8,561,829 B1**

(45) **Date of Patent: Oct. 22, 2013**

(54) **COMPOSITE PRESSURE VESSEL INCLUDING CRACK ARRESTING BARRIER**

(75) Inventor: **Thomas K. DeLay**, Huntsville, AL (US)

(73) Assignee: **The United States of America as Represented by the Administrator of the National Aeronautics and Space Administration**, Washington, DC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/544,066**

(22) Filed: **Jul. 9, 2012**

Related U.S. Application Data

(63) Continuation of application No. 12/604,954, filed on Oct. 23, 2009, now abandoned.

(51) **Int. Cl.**
F17C 1/06 (2006.01)
F17C 1/16 (2006.01)

(52) **U.S. Cl.**
CPC ***F17C 1/16*** (2013.01); ***F17C 1/06*** (2013.01)
USPC **220/588**

(58) **Field of Classification Search**
USPC .... 220/588, 586, 581, 62.19, 62.11, 220/560.12, 560.04, FOR. 127; 206/0.6
IPC B65D 1/40,3/22, 90/02; F17C 1/16, F17C 1/06, 1/04
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,364,786	A	*	1/1921	Samuel	442/64
1,651,521	A	*	12/1927	Lucas-Girardville	220/589
2,253,093	A	*	8/1941	Ludwig et al.	138/150
2,744,043	A	*	5/1956	Ramberg	156/155
3,150,792	A	*	9/1964	Bright	220/62.19
3,198,687	A	*	8/1965	Royet	428/138
3,207,352	A	*	9/1965	Reinhart, Jr.	220/589
3,390,703	A	*	7/1968	Matlow	138/114
4,004,706	A	*	1/1977	Guldenfels et al.	220/586
4,674,674	A		6/1987	Patterson et al.	
4,842,909	A		6/1989	Brassell	
5,202,165	A		4/1993	Lusignea et al.	
5,429,845	A	*	7/1995	Newhouse et al.	428/34.1
5,632,151	A		5/1997	Baker et al.	
5,840,802	A	*	11/1998	DeRudder et al.	525/63
2002/0179603	A1	*	12/2002	Darras et al.	220/62.11
2004/0020932	A1		2/2004	Brunnhofer	
2004/0040969	A1	*	3/2004	DeLay et al.	220/586
2004/0089440	A1		5/2004	Sanders	
2004/0256395	A1		12/2004	Lak et al.	
2006/0054628	A1		3/2006	Matsuoka et al.	
2006/0169704	A1		8/2006	Brunnhofer	

FOREIGN PATENT DOCUMENTS

EP	0379822	B1	8/1990
JP	58121399	A	7/1983
JP	2006062320	A	3/2006
WO	91/02645	A1	3/1991
WO	00/18225	A1	4/2000
WO	2004/044477	A2	5/2004

* cited by examiner

Primary Examiner — Jacob K Ackun

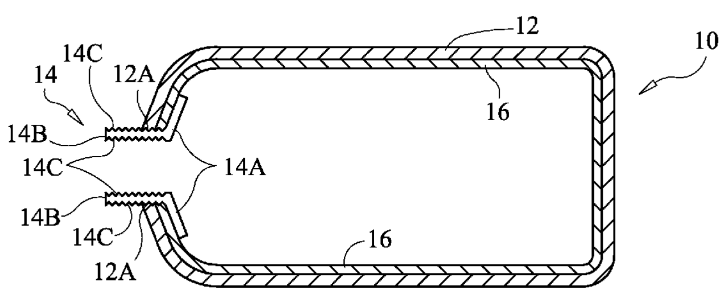
Assistant Examiner — Robert J Hicks

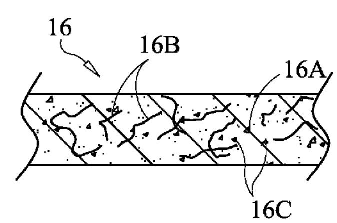
(74) *Attorney, Agent, or Firm* — Peter J. Van Bergen; James J. McGroary

(57) **ABSTRACT**

A pressure vessel includes a ported fitting having an annular flange formed on an end thereof and a tank that envelopes the annular flange. A crack arresting barrier is bonded to and forming a lining of the tank within the outer surface thereof. The crack arresting barrier includes a cured resin having a post-curing ductility rating of at least approximately 60% through the cured resin, and further includes randomly-oriented fibers positioned in and throughout the cured resin.

14 Claims, 1 Drawing Sheet





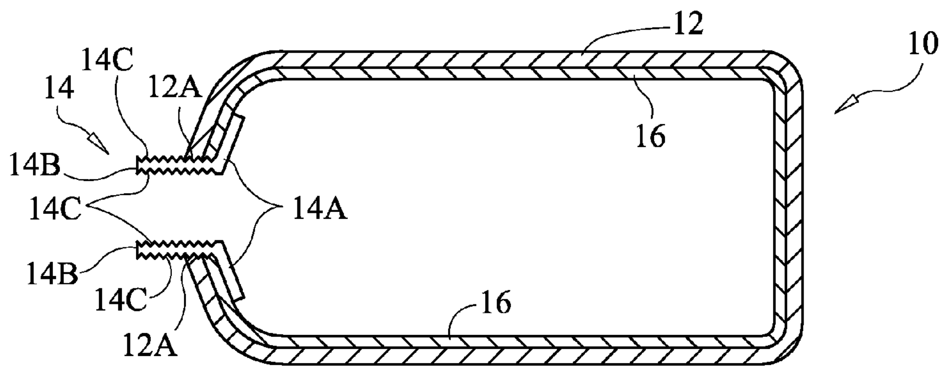


FIG. 1

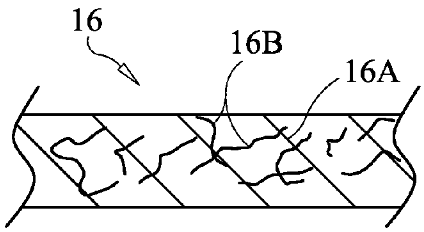


FIG. 2A

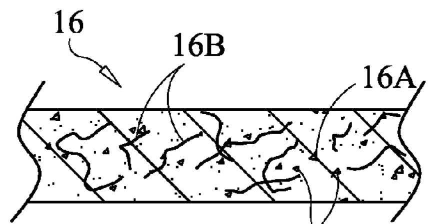


FIG. 2B

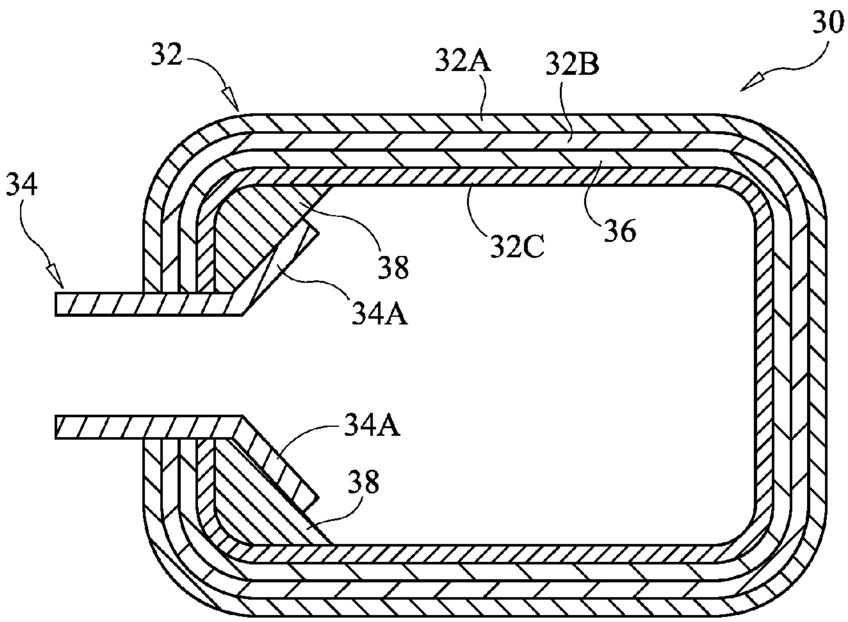


FIG. 3

COMPOSITE PRESSURE VESSEL INCLUDING CRACK ARRESTING BARRIER

CROSS-REFERENCES TO RELATED APPLICATIONS

This application is a continuation application of U.S. patent application Ser. No. 12/604,954, filed on Oct. 23, 2009 now abandoned.

ORIGIN OF THE INVENTION

The invention described herein was made by an employee of the United States Government and may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to pressure vessels. More specifically, the invention is a composite pressure vessel that includes a crack arresting barrier as part thereof.

2. Description of the Related Art

The aerospace industry relies heavily on the structural integrity of composite-based, cryogenic-fluid (e.g., liquid hydrogen) storage tanks for its space vehicles. Accordingly, the aerospace industry is very concerned about the formation and propagation of micro-cracks in composite tanks as such cracks can affect a tank's structural performance and provide paths for gas permeation through the tank's wall. While studies quantifying the micro-cracking phenomena are ongoing, methods/system for stopping such crack propagation do not exist. Most current efforts involve process enhancement of "off the shelf" composite tank material and structures, i.e., an orderly wound fiber tank structure permeated with a matrix resin. Current micro-crack studies have demonstrated that crack growth in such composite structures occurs in the matrix resin and travels along the ordered fiber windings. The cracking of the matrix resin affects structural integrity and also provides a leak path for gasses that are to be contained by the structure.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a pressure vessel that resists cracking.

Another object of the present invention is to provide a pressure vessel that arrests crack propagation.

Still another object of the present invention is to provide a pressure vessel suitable for use in the storage of cryogenic fluids.

Other objects and advantages of the present invention will become more obvious hereinafter in the specification and drawings.

In accordance with the present invention, a pressure vessel includes a rigid ported fitting having an annular flange formed on an end thereof and a rigid tank enveloping the annular flange. The ported fitting fauns an opening of the tank that has an inner surface and an outer surface. A crack arresting barrier is bonded to the tank and forms a lining of the tank within the outer surface thereof. The crack arresting bather also envelopes the annular flange. The crack arresting barrier includes a cured resin having a post-curing ductility rating of at least approximately 60% throughout the cured resin, and further includes randomly-oriented fibers positioned in and throughout the cured resin.

BRIEF DESCRIPTION OF THE DRAWING(S)

Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

FIG. **1** is a cross-sectional view of a composite pressure vessel incorporating a crack arresting barrier in accordance with an embodiment of the present invention;

FIG. **2**A is an isolated cross-sectional view of a crack arresting barrier in accordance with an embodiment of the present invention;

FIG. **2**B is an isolated cross-sectional view of a crack arresting barrier in accordance with another embodiment of the present invention; and

FIG. **3** is a cross-sectional view of a composite pressure vessel incorporating a crack arresting barrier in accordance with another embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring now to the drawings and more particularly to FIG. **1**, a pressure vessel that includes a crack arresting barrier in accordance with the present invention is illustrated in cross-section and is referenced generally by numeral **10**. The size and shape of pressure vessel **10** are not limitations of the present invention as size/shape are typically dictated by the particular application. In general, pressure vessel **10** can be used to contain a fluid material (e.g., gas or liquid) under pressure.

In the illustrated embodiment, pressure vessel **10** includes an outer rigid tank **12** that can be constructed in accordance with a variety of known processes/materials. For example, if pressure vessel **10** is to contain cryogenic fluids, tank **12** could be a composite wrapped structure, i.e., an orderly arrangement of fiber (e.g., carbon fiber) wraps held together in a rigid fashion by a resin matrix that permeates the fiber wraps. Tank **12** has an open-end **12**A for receiving a fitting **14** that defines the fluid entry/exit port of pressure vessel **10**. Generally speaking, fitting **14** is an open-ended sleeve of rigid material (e.g., metal) having a flared end **14**A that is captured within tank **12** adjacent open-end **12**A. That is, flared end **14**A is essentially an annular flange of fitting **14** that extends radially outward beyond the confines of open-end **12**A. A portion **14**B of fitting **14** that extends from open-end **12**A can be threaded internally and/or externally as indicated at **14**C.

Pressure vessel **10** also includes a continuous crack arresting bather **16** that lines the inside surface area of tank **12** and is disposed between flared end **14**A and tank **12**. In general, barrier **16** bonds to the inside surface of tank **12** as well as flared end **14**A of fitting **14**. The construction and placement of bather **16** resists cracking and also serves to arrest the propagation of any cracks that do form. Possible constructions for barrier **16** will be explained with reference to FIGS. **2**A and **2**B where isolated cross-sectional views of a portion of barrier **16** are presented.

FIG. **2**A illustrates an embodiment of barrier **16** that is defined by a resin **16**A (i.e., indicated by cross-hatching) that incorporates randomly oriented fibers **16**B therein. Resin **16**A is any resin matrix material that remains ductile after

curing. For many cryogenic applications the ductility rating of resin **16**A is at least approximately 60%, i.e., cured resin **16**A can be elongated by 60% prior to failure at room temperature. Fibers **16**B can originate as individual fibers that are mixed/dispersed within resin **16**A prior to the curing thereof. Fibers **16**B can also be in the form. of a felt material in which case resin **16**A permeates the felt material composed of fibers **16**B. Accordingly, it is to be understood that the means and methods for constructing barrier **16** are not limitations of the present invention as barrier **16** could be laid up, sprayed on, etc., the inner surface of tank **12**.

FIG. **2**B illustrates another embodiment of barrier **16** that includes resin **16**A and fibers **16**B as described above, and further includes nano-sized particles **16**C mixed in resin **16**A. Particles **16**C can be any of a variety of organic or inorganic filler particles. When included in barrier **16**, particles **16**C aid in the prevention of gas permeation through barrier **16** if a micro-crack should develop.

Regardless of its particular construction details, crack arresting barrier **16** functions as follows. In terms of crack resistance, the ductility of resin **16**A allows barrier **16** to yield or flex without cracking. Thus is important as pressure vessel **10** experiences pressure cycles. Since pressure vessel **10** does not rely on barrier **16** for strength, such yielding of barrier **16** does not impact the structural integrity of pressure vessel **10**. Furthermore, this yielding feature of barrier **16** allows it to also function as a shear ply between tank **12** and fitting **14**. More specifically, barrier **16** bonds to both tank **12** (near open end **12**A) and flared end **14**A, and yields to shear forces that can develop between tank **12** and flared end **14**A during pressure cycling. Accordingly, even though barrier **16** does not possess the strength of the materials used for tank **12** and fitting **14**, barrier **16** contributes to the overall structural integrity of pressure vessel **10** by forming a shear ply between tank **12** and flared end **14**A. Still further, in the event that a micro-crack develops in bather **16**, propagation of such a crack is limited by the random orientations of fibers **16**B. That is, the random orientations of fibers **16**B interrupt cracks in barrier **16**.

It is to be understood that the present invention is not limited to the pressure vessel construction described above. For example, FIG. **3** illustrates a pressure vessel **30** that includes a rigid tank **32** made from multiple layers such as three rigid layers **32**A, **32**B and **32**C. The particular construction of layers **32**A-**32**C is not a limitation of the present invention. A rigid fitting **34** is disposed in tank **32** with a flared end **34**A thereof being disposed adjacent inner most layer **32**C. Pressure vessel **30** also includes a crack arresting barrier **36** disposed continuously between layers **32**B and **32**C. Note that barrier **36** additionally or alternatively be placed between layers **32**A and **32**B without departing from the scope of the present invention. Barrier **36** is a ductile composite configured as one of the above-described embodiments of barrier **16**. In addition, pressure vessel **30** includes a flexible collar **38** disposed between and coupled to tank layer **32**C and flared end **34**A. Collar **38** is also a ductile composite configured as one of the above-described embodiments of barrier **16**. Accordingly, collar **38** forms a shear ply between tank **32** and fitting **34**.

The advantages of the present invention are numerous. A simple crack arresting barrier of a ductile resin incorporating randomly oriented fibers improves the overall structural integrity of a pressure vessel by inhibiting crack formation/propagation and gas permeation. The barrier can also form a shear ply between the vessel's rigid tank and rigid ported fitting. The design is suitable for use in cryogenic and non-cryogenic applications.

Although the invention has been described relative to a specific embodiment thereof, there are numerous variations and modifications that will be readily apparent to those skilled in the art in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

The invention claimed is:

1. A pressure vessel, comprising:

a rigid ported fitting having an annular flange formed on an end thereof;

a rigid tank enveloping said annular flange wherein said ported fitting forms an opening of said tank, said tank having an inner surface and an outer surface; and

a crack arresting barrier bonded to and forming a lining of said tank within said outer surface thereof, said crack arresting barrier enveloping said annular flange, said crack arresting barrier including a cured resin having a post-curing ductility rating of at least approximately 60% throughout said cured resin, said crack arresting barrier further including (i) randomly-oriented fibers positioned in and throughout said cured resin, and (ii) nano-sized particles mixed in said cured resin.

2. A pressure vessel as in claim **1**, wherein said tank is a composite wrapped tank.

3. A pressure vessel as in claim **1**, wherein said crack arresting barrier comprises a continuous layer disposed between the entirety of said outer surface of said tank and the entirety of said inner surface of said tank.

4. A pressure vessel as in claim **1**, wherein said crack arresting barrier comprises a continuous layer bonded to the entirety of said inner surface of said tank and bonded to said annular flange.

5. A pressure vessel as in claim **1**, wherein said fibers are incorporated in a felt material.

6. A pressure vessel as in claim **1**, wherein said fibers are individual fibers dispersed in said cured resin.

7. A pressure vessel, comprising:

a cryogenic tank having an open end;

an open-ended sleeve having a threaded end and a flared end with said flared end disposed in said open end of said cryogenic tank; and

a crack arresting barrier lining and bonded to the inside surface area of said cryogenic tank, said crack arresting barrier bonded to said flared end of said sleeve, said crack arresting barrier including a cured resin having a post-curing ductility rating of at least approximately 60% throughout said cured resin, said crack arresting barrier further including (i) randomly-oriented fibers positioned in and throughout said cured resin, and (ii) nano-sized particles mixed in said cured resin.

8. A pressure vessel as in claim **7**, wherein said cryogenic tank is a composite wrapped tank.

9. A pressure vessel as in claim **7**, wherein said fibers are incorporated in a felt material.

10. A pressure vessel as in claim **7**, wherein said fibers are individual fibers dispersed in said cured resin.

11. A pressure vessel as in claim **7**, wherein said sleeve is a metal sleeve.

12. A pressure vessel, comprising:

a tank having an open end;

an open-ended sleeve having a threaded end and a flared end with said flared end disposed in said open end of said tank; and

a crack arresting barrier lining and bonded to the inside surface area of said tank, said crack arresting barrier bonded to said flared end of said sleeve, said crack

arresting barrier including a felt permeated with a cured resin having nano-sized particles mixed in and throughout said cured resin, said cured resin having a post-curing ductility rating of at least approximately 60% throughout said cured resin.

13. A pressure vessel as in claim **12**, wherein said tank is a composite wrapped tank.

14. A pressure vessel as in claim **12**, wherein said sleeve is a metal sleeve.

* * * * *